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(54) **ACCUMULATOR FOR CHARGE MANAGEMENT**

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F25D 1/00 (2006.01)
F25B 49/00 (2006.01)
F25B 41/00 (2006.01)
F25B 49/02 (2006.01)

(52) **U.S. Cl.**

CPC ***F25B 45/00*** (2013.01); ***F25B 41/00*** (2013.01); ***F25B 49/005*** (2013.01); ***F25B 49/02*** (2013.01); ***F25D 1/00*** (2013.01); *F25B 2345/002* (2013.01); *F25B 2345/003* (2013.01); *F25B 2600/05* (2013.01); *F25B 2600/2513* (2013.01); *F25B 2700/04* (2013.01)

(58) **Field of Classification Search**

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USPC 62/174, 103
See application file for complete search history.

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(57) **ABSTRACT**

Embodiments of an accumulator for charge management are described. A fluid compression system, comprising an accumulator fluidly connected to an evaporator via a spillover port. The spillover port directs working fluid received from the evaporator to be collected and stored in the accumulator, where the stored working fluid is stored and released from the accumulator in response to an operating condition of the evaporator.

18 Claims, 6 Drawing Sheets

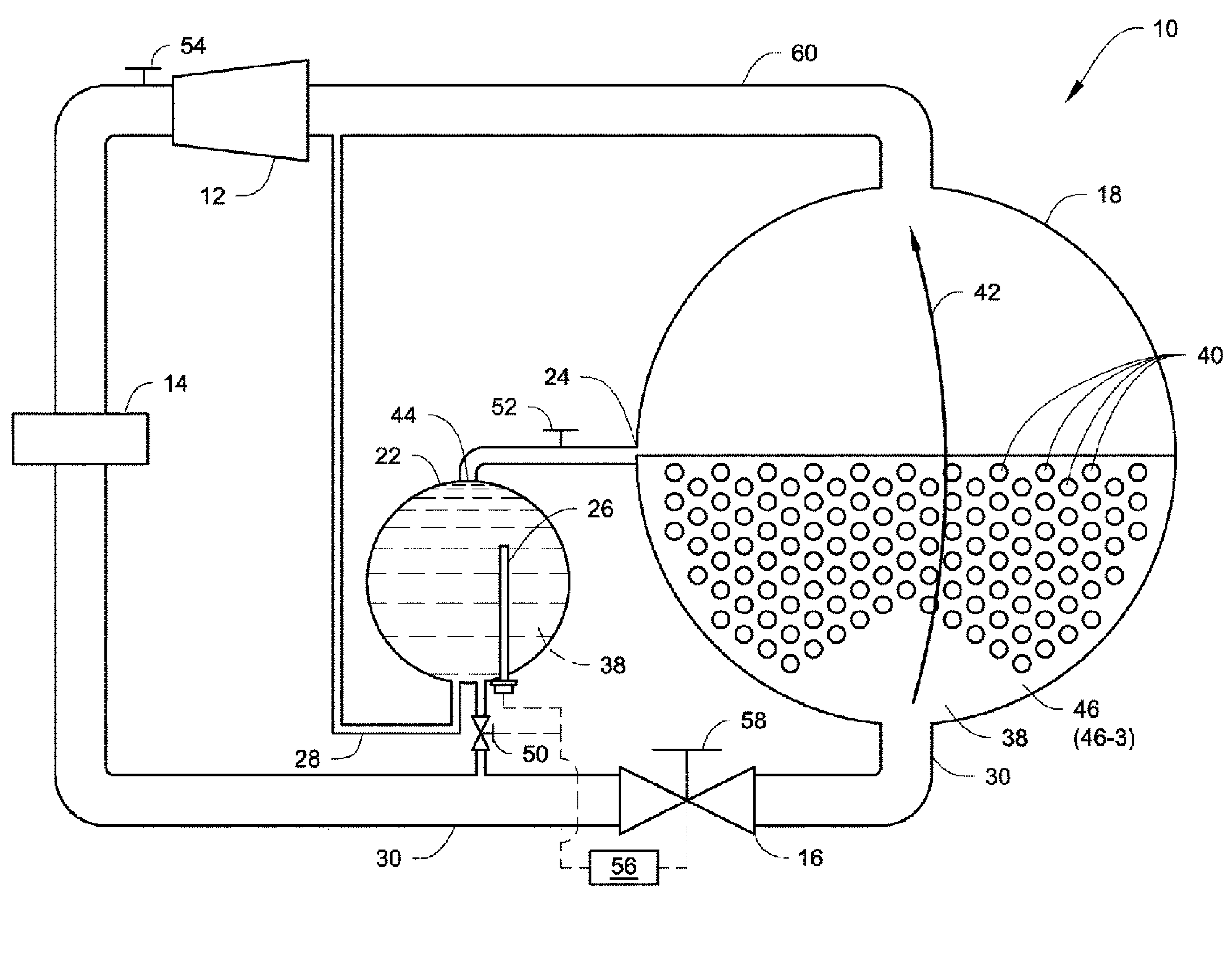
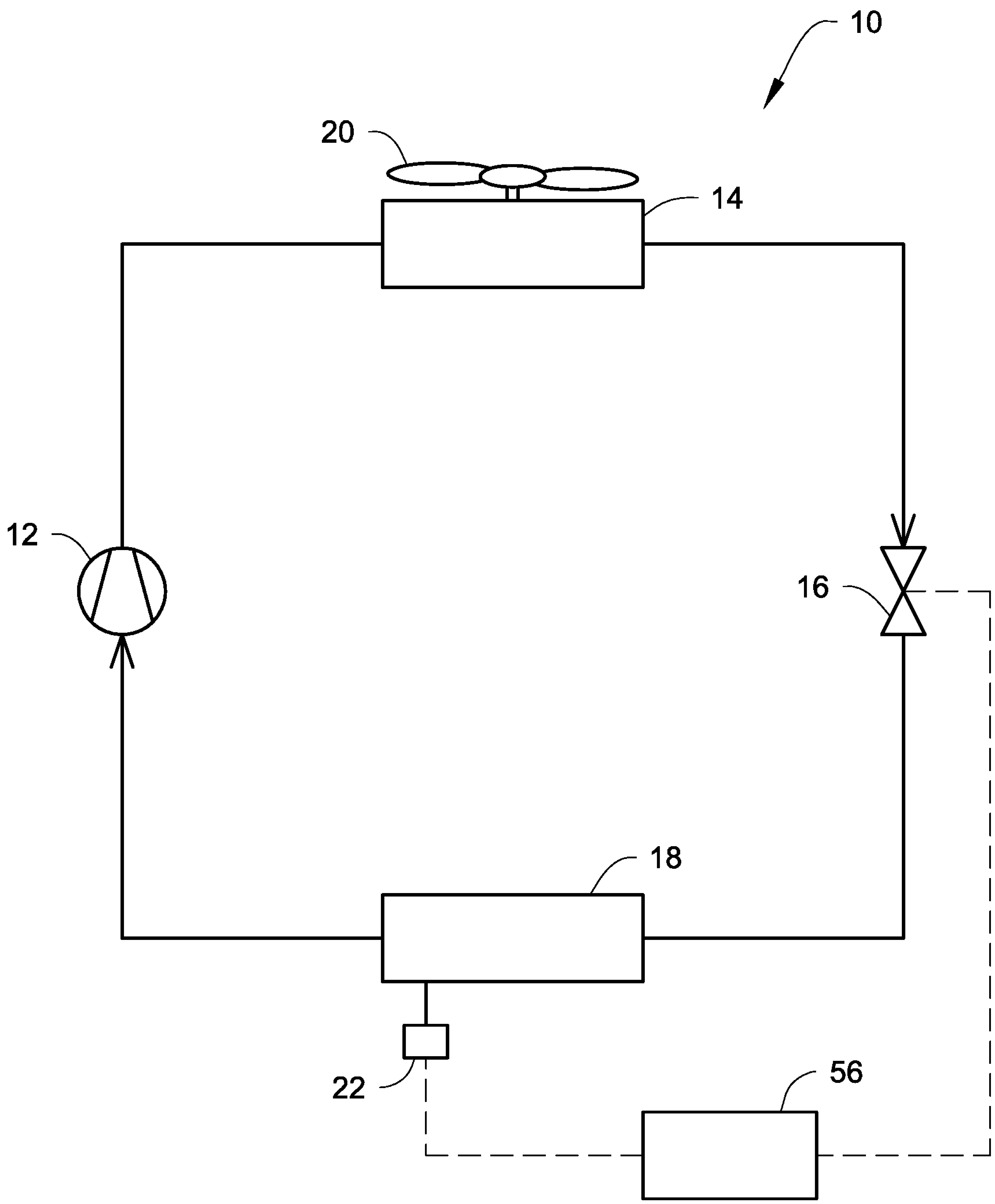


Fig. 1



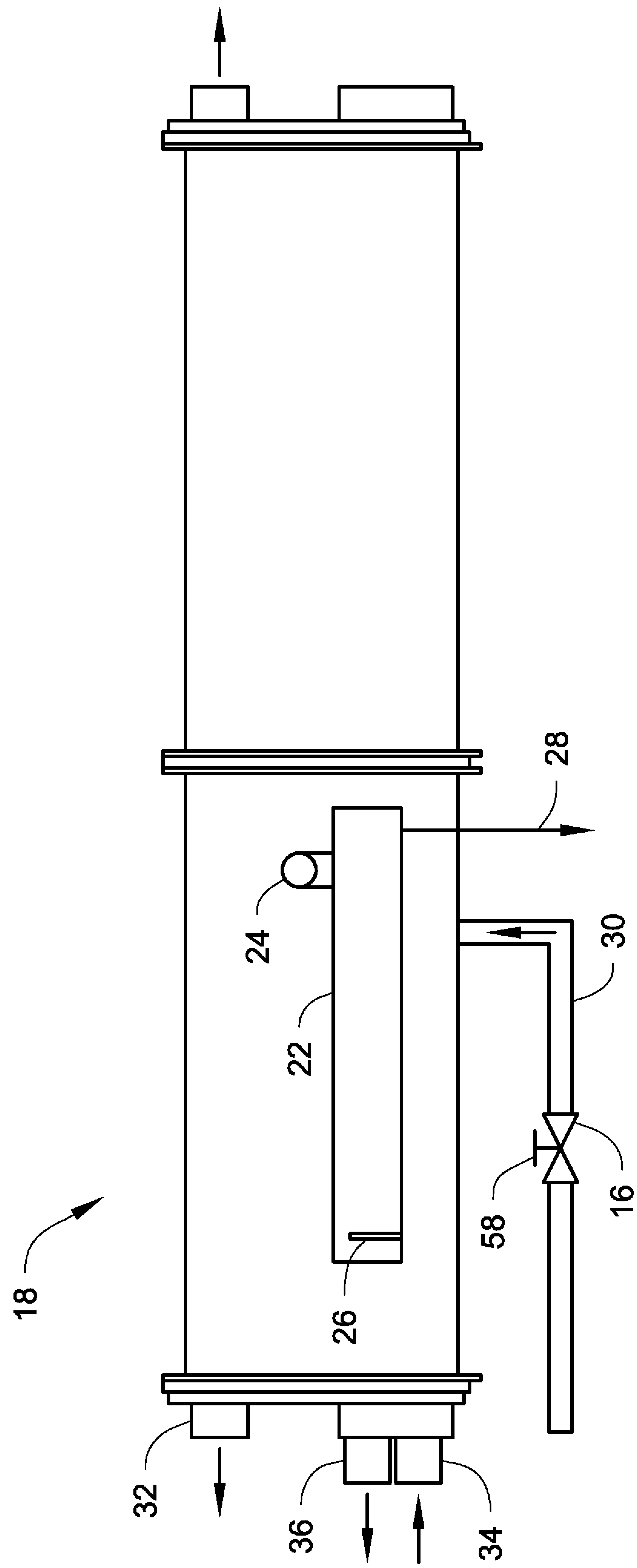


Fig. 2

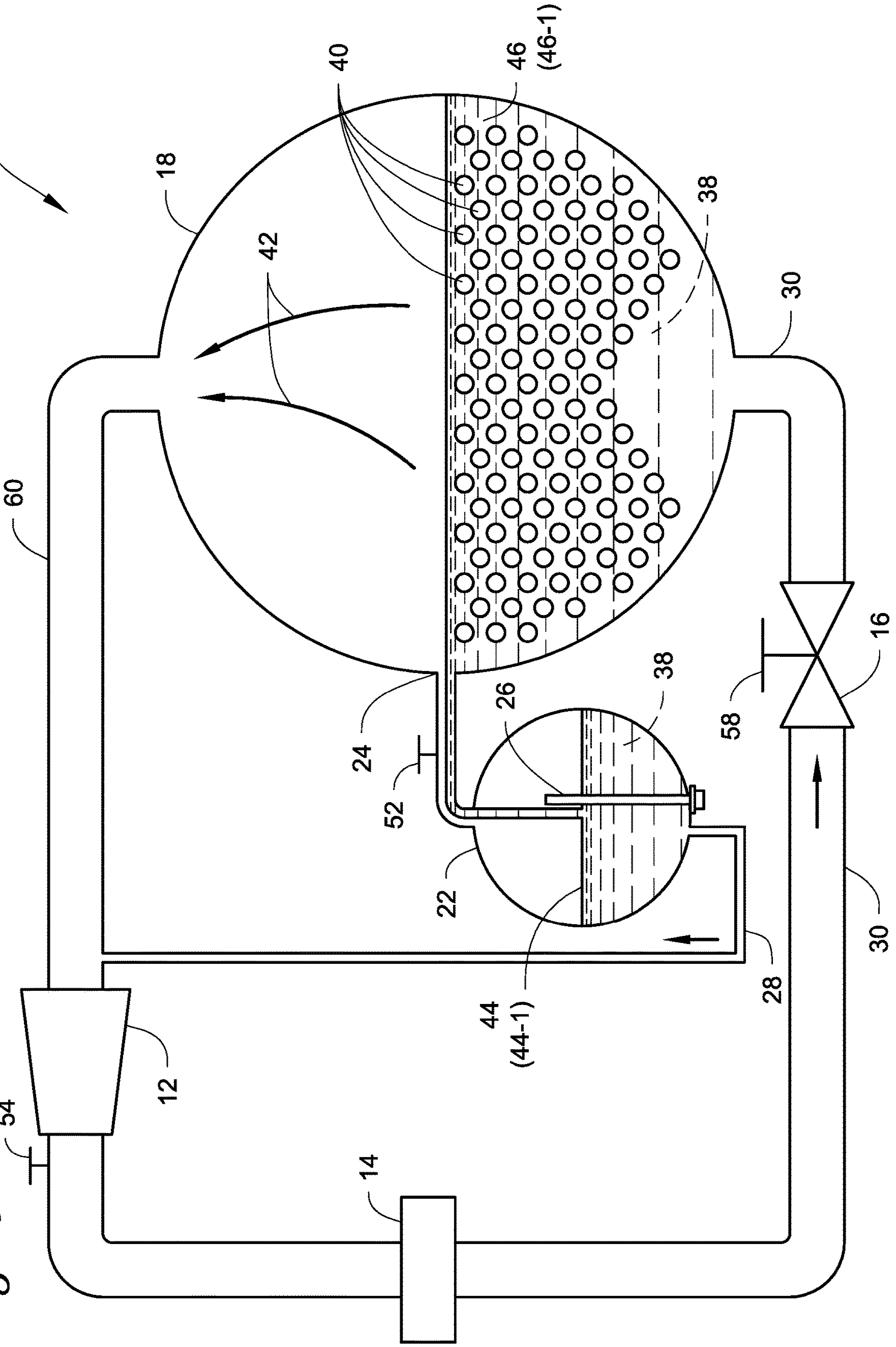


Fig. 3A

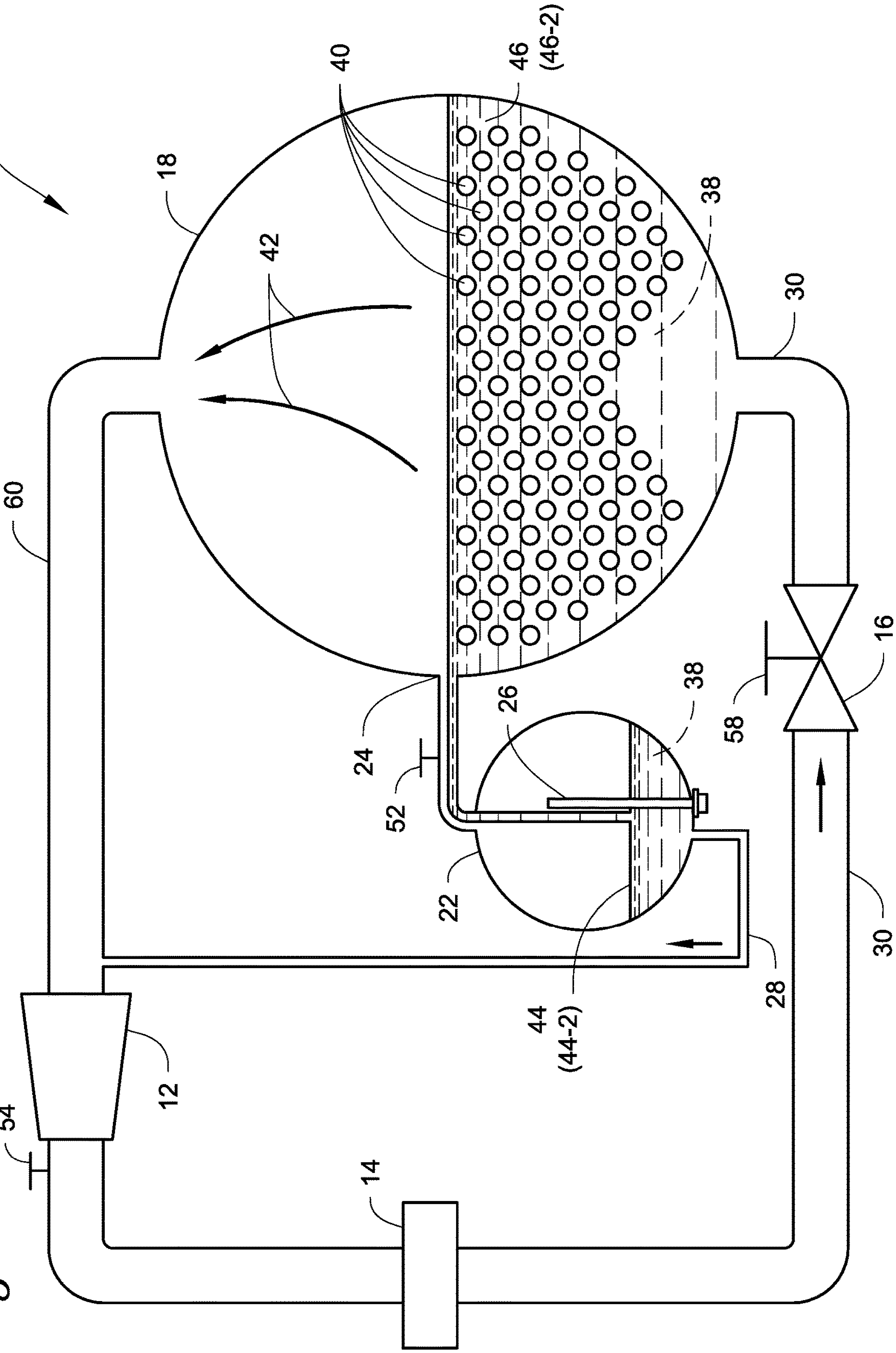


Fig. 3B

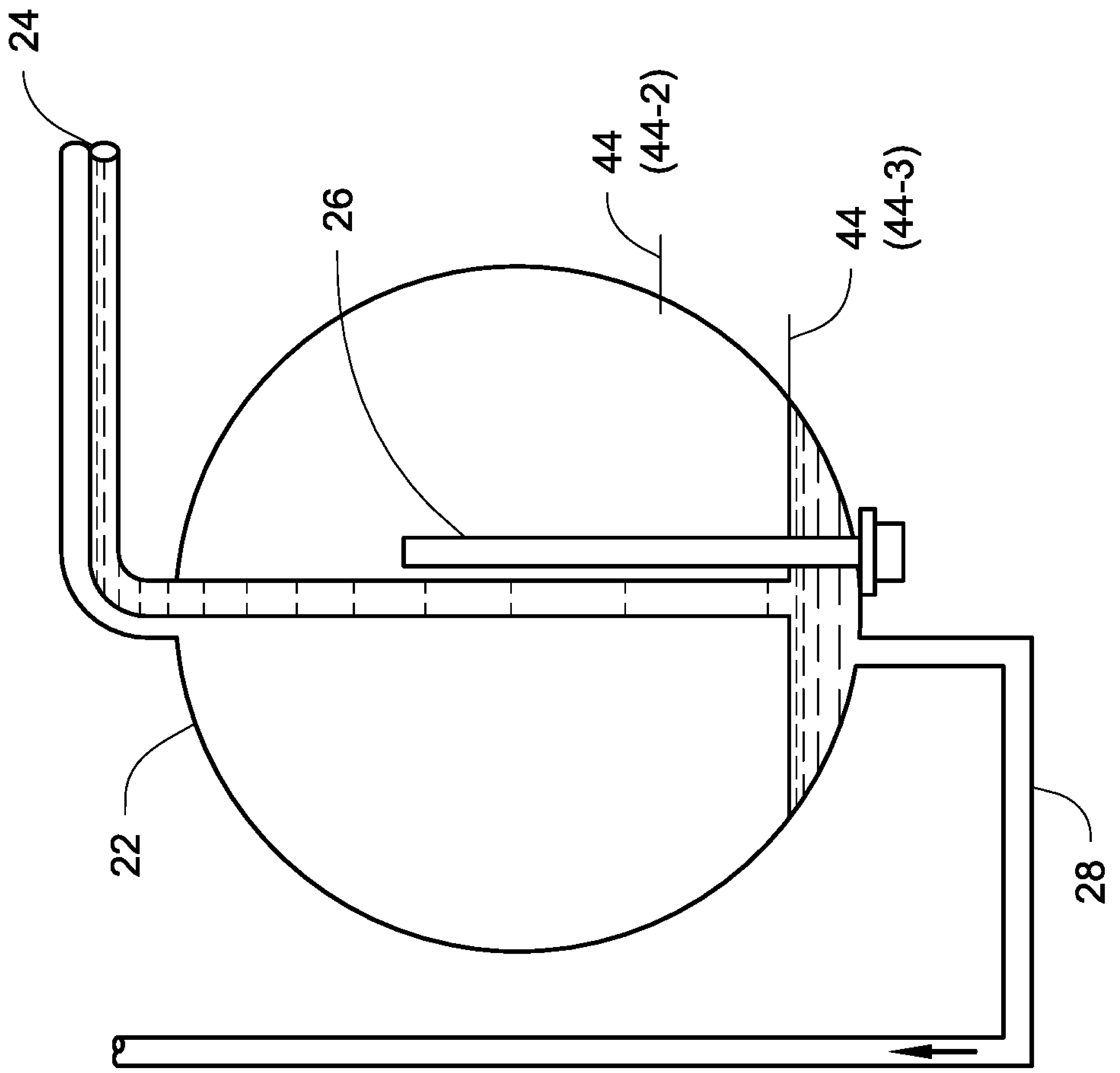


Fig. 4

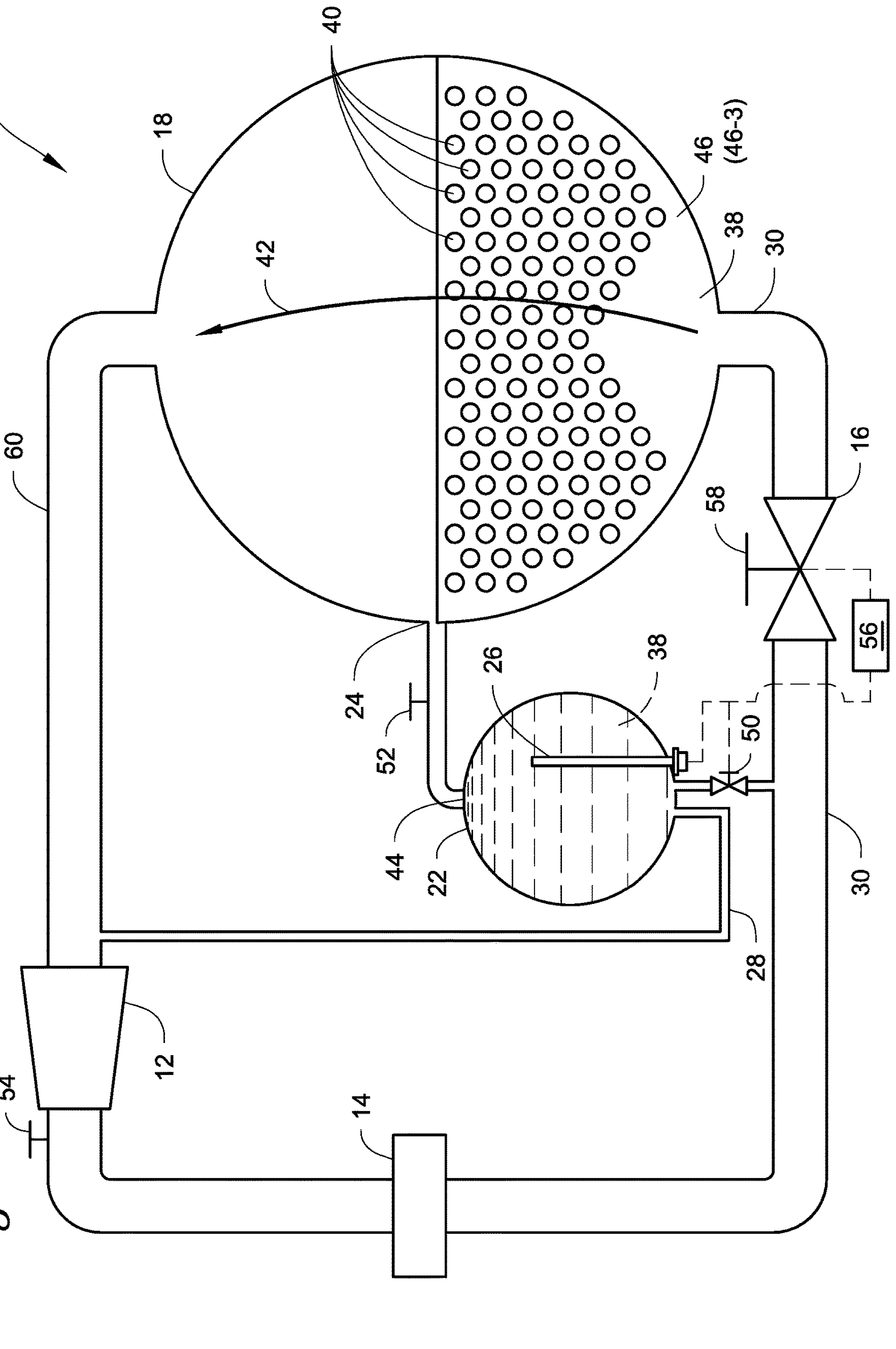


Fig. 5

ACCUMULATOR FOR CHARGE MANAGEMENT

FIELD

The disclosure herein relates to a fluid compression system, and may be implemented in a chiller unit as part of an HVACR system, and more particularly, to an accumulator for charge management in a fluid compression system. Generally, methods, systems, and apparatuses are described that are directed to charge management (e.g., refrigerant, coolant, etc.) in an evaporator, such as may be used in a fluid compression system.

BACKGROUND

A fluid compression system (e.g., a chiller unit as part of an HVACR system), typically includes a compressor, a condenser, an evaporator and an expansion device forming a refrigeration circuit. The evaporator may be a flooded or falling-film evaporator, which often has a construction of a tube bundle within a shell. Such evaporators are typically used in fluid compression systems to cool a process fluid (e.g., water) flowing in the tube bundle which, in turn, is typically used in connection with a heat exchanger coil or air-handling unit to cool air moving through the coil or air-handling unit. The tube bundle is often stacked up from a bottom of the evaporator. In a flooded evaporator, the tube bundle is covered with working fluid, such as refrigerant, in the shell to help maximize heat exchange between the refrigerant and the process fluid.

The compressor of the fluid compression system often requires lubricant, such as oil, to lubricate moving parts of the compressor. In the fluid compression system, the lubricant may circulate in the refrigeration circuit along with the refrigerant, and then return to the compressor.

SUMMARY

The disclosure herein relates to a fluid compression system, such as may be implemented in e.g., a chiller unit as part of an HVACR system, and more particularly to an accumulator for charge management in the fluid compression system.

Improving fluid management in a fluid compression system can help increase efficiency of the fluid compression system. The fluid management as described herein generally includes managing a charge (e.g., working fluid, refrigerant, coolant, water, lubricant, etc.) in the fluid compression system by incorporating an accumulator (e.g., a reservoir, spill over storage tank). The accumulator can manage the charge such that the fluid compression system may have increased efficiency and/or operate over a broader range of operating conditions and/or charge levels.

Embodiments disclosed herein may use an accumulator fluidly connected to an evaporator to aid in charge management of a fluid compression system, such as a chiller unit as part of an HVACR system. The accumulator can help improve charge management in the fluid compression system by storing and/or providing a desired level of working fluid to the fluid compression system.

In an embodiment, a fluid compression system may comprise an accumulator fluidly connected to an evaporator via a spillover port. The spillover port directs working fluid received from the evaporator to be collected and stored in the accumulator, where the working fluid is stored and released from the accumulator in response to an operating condition of the evaporator. Operating conditions are relative to a charge level of the evaporator. In an embodiment, the working fluid can be released from the accumulator to a first conduit and provided to the fluid compression system.

In an embodiment, an indicator is located at least partially within the accumulator. The indicator can be a level sensor, a site glass, an optical sensor, or the like. The indicator detects a working fluid level (e.g., a level of refrigerant, working fluid, etc.) stored within the accumulator. The detected working fluid level corresponds to a particular operating condition of the evaporator.

In an embodiment, the indicator can be configured to provide an indication of a loss of charge (e.g., working fluid level loss) to a controller of the fluid compression system based on the detected working fluid level. Additionally, or alternatively, in some embodiments, the indicator can detect a transition condition. A transition condition is a detected working fluid level in the accumulator correlating to a loss of working fluid in the evaporator for less than a threshold time and prevents a false alarm.

In an embodiment, the accumulator in some systems can store approximately 1 to 2 cubic feet (e.g., approximately 10 gallons) of working fluid. In an embodiment, a substantial amount or all of the charge from the evaporator can be stored in the accumulator to prevent freezing of the evaporator during a shut-down operation, as discussed further herein. For example, the accumulator can store a portion (e.g., less than 10 gallons) of the working fluid or all (e.g., approximately 10 gallons) of the working fluid **38**.

In an embodiment, a fill and drain valve can be connected to the accumulator to drain the stored working fluid from the accumulator back to the evaporator until a mass flow rate of charge is established in the fluid compression system. For example, the working fluid stored in the accumulator can be provided to the evaporator until a charge spillover rate is established. Additionally, or alternatively, actuation of the fill and drain valve is dependent upon a detected loss of working fluid above a threshold time that corresponds to a loss of working fluid in the evaporator in the fluid compression system, as discussed further herein.

In an embodiment, an expansion device is located between the fill and drain valve and the evaporator. The expansion device restricts a flow of charge from a second conduit to the evaporator.

An accumulator to manage charge in a fluid compression system can be advantageous for chiller performance. Charge stored in the accumulator can enable the chiller to operate at an increased efficiency, and/or operate over a broad range of operating conditions and/or charge levels. For example, minor charge loss in the fluid compression system may have little to no effect on an operating efficiency of the chiller. Additionally, or alternatively, the accumulator may be a device that can help a manufacturing/repair factory/user correctly charge the chiller. The accumulator fluidly connected to the evaporator can enable a fluid compression system to be more robust to charge variations by improving tolerance to overcharge and/or undercharge.

Other features and aspects of charge management approaches will become apparent by consideration of the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference is now made to the drawings in which like reference numbers represent corresponding parts throughout.

FIG. **1** is a schematic view of a fluid compression system, which includes a compressor, heat exchanger as a condenser, expansion device, an evaporator, and an accumulator according to an embodiment.

FIG. **2** illustrates an accumulator fluidly connected to an evaporator in a fluid compression system according to an embodiment.

FIG. **3**A illustrates the accumulator in the fluid compression system according to a first embodiment.

FIG. **3**B illustrates the accumulator in the fluid compression system according to a second embodiment.

FIG. **4** illustrates the accumulator in the fluid compression system, according to a third embodiment.

FIG. **5** illustrates the accumulator in the fluid compression system according to a fourth embodiment.

DETAILED DESCRIPTION

In a fluid compression system, such as a chiller unit as part of an HVACR system, fluid management may involve management of charge, such as refrigerant, coolant, water, etc., in a cooling circuit that is typically formed by a compressor, a condenser, an evaporator and an expansion device. The fluid compression system may incorporate methods and systems to manage charge.

In a chiller unit as part of an HVACR system, for example, a broad range of operating conditions (e.g. full and partial loads) and/or charge levels can affect a chiller performance. Proper charge (e.g., working fluid, refrigerant, etc.) in a chiller is important for optimal performance and/or energy efficiency. For example, when charge enters the compressor the chiller performance is reduced, power consumption is increased, and/or damage to the system may occur. Alternatively, an insufficient charge in a chiller may cause heat exchange tubes of the evaporator to be exposed, leading to evaporator dry out. Additionally, water temperature stratification may occur, which can affect a water temperature leaving the evaporator and negatively impact partial load efficiency, and may result in a frozen evaporator.

As described herein, an accumulator can provide charge management in a fluid compression system, such as a chiller unit as part of an HVACR system. The fluid compression system can include an accumulator fluidly connected to an evaporator via a spillover port. The spill over port is fluidly connected to the evaporator, and the spillover port directs working fluid received from the evaporator to be collected and stored in the accumulator. The working fluid is stored and released from the accumulator based on a particular operating condition of the evaporator.

The accumulator fluidly connected to the evaporator in the system can be advantageous for chiller performance. Working fluid stored in the accumulator can enable the chiller to operate at an increased efficiency, and/or operate over a broad range of evaporator operating conditions and/or accumulator working fluid levels. For example, a portion of charge loss may have little to no effect on an operating efficiency of the chiller. Additionally, or alternatively, the accumulator may be a device that can help a manufacturing/repair factory/user properly charge the chiller by using information related to a working fluid level of the accumulator and/or operating condition relevant to the evaporator. Additionally, or alternatively, the accumulator may enable a chiller to be more robust to charge variations by improving tolerance to overcharge and/or undercharge due to the storage capability of the accumulator.

FIG. **1** is a schematic view of a fluid compression system **10**, which includes a compressor **12**, a condenser **14**, expansion device **16**, an evaporator **18**, and an accumulator **22** according to an embodiment. In an embodiment, the fluid compression system **10** can be a fluid chiller unit as part of an HVACR system. The fluid chiller can be an air-cooled fluid chiller and may be charged with refrigerant as a working fluid. In an embodiment, the condenser **14** of the fluid compression system **10** is an air-cooled condenser employing a fan **20**. In another embodiment, the condenser **14** can be a water cooled condenser.

The fluid compression system **10** directs the working fluid, such as a refrigerant and lubricant mixture, through the circuit of FIG. **1**. It will be appreciated that the working fluid may be fluids other than refrigerant, such as water, coolant, etc., or may be a single component (e.g., a single refrigerant), and/or include various components (e.g., blends) including one or more refrigerants, as well as one or more lubricants, additives, and other fluids. The charge and any of its components can be present in various phases such as for example vapor and/or liquid, depending on where it is in the circuit of the fluid compression system **10**, such as for example during a cooling operation. As used herein, charge and working fluid are used interchangeably herein, and charge can be associated with respect to the evaporator.

The compressor **12** compresses the working fluid, and directs the working fluid to the condenser **14**. The condenser **14** condenses the working fluid from a vapor to a liquid and directs the working fluid to the expansion device **16**. The condenser **14** in some cases can employ a fan **20** which draws a heat exchanger fluid, such as for example air, across the condenser **14** to condense the working fluid. The condenser **14** may include one or more heat exchanger coils which pass the working fluid through the condenser **14**. The expansion device **16** expands the working fluid to further cool the working fluid, where the working fluid can become a mixed vapor liquid phase fluid. The working fluid is directed to the evaporator **18**, where the working fluid is evaporated into a vapor. The evaporator **18** can include a heat exchanger, such as a tube bundle, that is stacked from a bottom of the evaporator **18**. The tube bundle can vaporize the working fluid (e.g., refrigerant, oil, etc.) within the evaporator **18**. The working fluid may then return to the compressor **12** and be recirculated through the circuit.

In an embodiment, the fluid compression system **10** includes an accumulator **22** positioned externally to the evaporator **18**. The accumulator **22** is fluidly connected to the evaporator **18**. The accumulator **22** can serve as a reservoir that collects and stores working fluid from the evaporator **18**. The working fluid can include, for example, a mixture of refrigerant and lubricant (e.g., oil). The fluid compression system **10** includes a controller **56** that can be configured to control the expansion device **16** and/or the working fluid flow from the accumulator **22** to the evaporator **18**. The controller **56** is comprised of a combination of hardware and software configured to send and receive signals. For example, the controller **56** is configured to receive a working fluid level measured by an indicator, as discussed further herein.

In an embodiment, the condenser **14** includes a heat exchanger coil, which may be a microchannel heat exchanger coil (microchannel coil). A microchannel coil in some instances has flattened tubes that extend from one or more headers. A microchannel coil may have one or more rows of flattened tubes, be folded on itself, and may use the same header or have different headers connected to the ends of the flattened tubes. A microchannel coil has multiple channels within each of the flattened tubes and fins between the flattened tubes. As the capacity of the condenser **14** is reduced, the accumulator **22** fluidly connected to the evaporator **18** can store the charge during various states of operating conditions of the fluid compression system, such as at various loads, at shut-down, which are further discussed herein.

FIG. **2** illustrates an evaporator **18** with a spillover port **24** fluidly connecting an accumulator **22** in a fluid compression system. The accumulator **22** can act as a storage tank for an evaporator **18** in the fluid compression system. The accumulator **22** can be positioned externally to the evaporator **18**.

As illustrated in FIG. **2**, the spillover port **24** fluidly connects the evaporator **18** and the accumulator **22**. The spillover port **24** directs working fluid (e.g., refrigerant, refrigerant/lubricant mixture, etc.) received from the evaporator **18** to be collected and stored in the accumulator **22**. The accumulator **22** further includes a first conduit **28** that serves as a lubricant return line. For example, the working fluid containing lubricant (e.g., oil) can drain from the accumulator **22** and into the first conduit **28**. In some instances, oil may eventually collect in the evaporator **18**, as discussed further herein.

An indicator **26** can be located at least partially within the accumulator **22**. In some embodiments, the indicator **26** can be a level sensor that detects a working fluid level in the accumulator **22**. The indicator **26** can detect working fluid level variations within the accumulator **22**. The working fluid level variations can include a full load level, a partial load level, and a working fluid loss level, as discussed further herein.

In some embodiments, the working fluid level collected within the accumulator **22** can change passively for example according to system operation (e.g. system pressures), thus eliminating a need for a controller. For example, the accumulator **22** can collect the working fluid from the evaporator **18** through the spillover port **24** via gravity (e.g., passively). Alternatively, in an embodiment, the working fluid may be collected and stored in the accumulator **22** non-passively, such as with use of a pump (not shown).

FIG. **2** further illustrates the evaporator **18** connected to an expansion device **16** and a second conduit **30** connected to the evaporator **18**. The expansion device **16** and second conduit **30** can direct working fluid to the evaporator **18**. The expansion device **16** includes an expansion valve **58**, which can be opened to direct working fluid to the evaporator **18** or closed to prevent working fluid from flowing to the evaporator **18**. In an embodiment, a fill and drain valve (not shown) can release working fluid stored in the accumulator **22** to be provided to the evaporator **18** for mass balance reestablishment, as discussed further herein. In an embodiment, the evaporator **18** is a flooded type evaporator.

The evaporator **18** further includes an evaporator outlet **32** for the working fluid to flow to the compressor inlet of a compressor (not shown), a water inlet **34**, and a water outlet **36** for water to flow in and out of the evaporator **18**.

FIG. **3**A-**5** illustrate the accumulator in the fluid compression system according to different embodiments. The fluid compression system **10** includes accumulator **22**, spill over port **24**, evaporator **18**, an indicator **26**, second conduit **30**, expansion device **16**, expansion valve **58**, compressor **12**, and condenser **14**, wherein these elements are similar to the like features shown and described with respect to FIGS. **1** and **2**. For simplicity, features which are the same and were previously described are not described in additional detail.

The spill over port **24** provides working fluid **38** from the evaporator **18** to the accumulator **22**. The working fluid **38** (e.g., refrigerant, lubricant, mixture, etc.) is transferred from the evaporator **18** to the accumulator **22** from a location with a high concentration of lubricant (e.g., oil). The accumulator **22** can store the working fluid **38** until such working fluid **38** is needed in the system, as discussed further herein.

The evaporator **18** can provide a charge spill-over rate to the accumulator **22**. The charge spill-over rate is an amount of working fluid **38** provided from the evaporator **18** to the accumulator **22** via the spill over port **24**. The charge spill-over rate can be an amount (e.g., a rate of flow over time) of working fluid **38** that varies based on an operating condition **46** associated with the evaporator **18**. That is, the charge spill-over rate is an amount of working fluid **38** that is provided from the evaporator **18** to the accumulator **22** over a period of time. In an embodiment, the charge spill-over rate may correlate with changes in operating condition **46** relative to the evaporator **18**. Generally, a charge spill-over rate may be less than or approximately 5% of a total compressor flow (e.g. mass flow of the working fluid). The charge spill-over rate may vary between approximately 0% and 5% of the compressor flow. The variation in charge spill-over rate can correlate to variations in operating condition **46**. For example, a steady state (e.g., constant) charge spill-over rate may be determined by a drain rate of the accumulator **22**. The drain rate is the amount of working fluid (e.g., refrigerant, lubricant, etc.) that flows from the accumulator **22**, through the first conduit **28**, and to the compressor **12**.

As previously mentioned, sufficient charge (e.g., working fluid **38**) is important for proper functioning of a fluid compression system **10**. As discussed further herein, a working fluid level **44** in the accumulator **22** can correspond to an operating condition **46** relative to the evaporator **18**. In an embodiment, the working fluid level **44** that correlates to an operating condition **46** relevant to the evaporator **18** can signify whether charge loss is a threat to proper functioning of the system **10**.

In an embodiment, the working fluid level **44** (e.g., an amount of working fluid **38** stored) in the accumulator **22** can correlate with the operating condition **46** of the system **10**. Since the charge spill-over rate transfers working fluid **38** from the evaporator **18** to the accumulator **22** via spill over port **24**, the working fluid level **44** in the accumulator **22** is dependent upon the particular operating condition **46** relevant to the evaporator **18**. That is, the amount of charge in the evaporator **18** affects the working fluid level **44** in the accumulator **22**. As such, the working fluid level **44** in the accumulator **22** can be used to indicate a correlating operating condition **46** relevant to the evaporator **18**.

In an embodiment, the indicator **26**, such as a level sensor, can detect a working fluid level **44** in the accumulator **22**. The indicator **26** can be within the accumulator **22** and submerged in the working fluid that accumulates from the spill over port **24**. The working fluid level **44** detected by the indicator **26** corresponds to the particular operating condition **46** relevant to the evaporator **18**. The working fluid level **44** in the accumulator **22** can change in response to the operating condition **46**, which is the amount of working fluid **38** in the evaporator **18**. In some circumstances, the working fluid level **44** in the accumulator **22** can change in response to changes in amounts of working fluid **38** associated with other components of the system **10**, such as but not limited to the condenser **14**, inter connecting piping (not shown), and other components of the fluid circuit which may or may not be shown. In an embodiment, the volume of charge in the evaporator **18** can be at or nearly constant, but the density of the working fluid **38** can change with the operating condition **46**. A density of the working fluid **38** can be inversely related to the void fraction of the fluid. The void fraction is the ratio of vapor to liquid in the working fluid **38**. The void fraction of the working fluid **38** can change as a direct function of the compressor **12** mass flow **42**.

As illustrated in FIGS. **3**A-**5**, the indicator **26** can be a level sensor. The indicator **26** can detect the working fluid level **44** within the accumulator **22** that corresponds to a particular operating condition **46** relative to the evaporator **18**. Although the indicator **26** associated with the accumulator **22** in FIGS. **3**A-**5** is depicted as a level sensor, it will be appreciated that the indicator **26** may be a site glass, optical sensor, visual inspection, and/or the like. For example, in some embodiments a site glass and/or an optical sensor could also be used such that detection of charge loss (e.g., working fluid loss level) is based on a visual inspection using the site glass and/or optical sensor (not shown). For instance, the level sensor **26** can be a site glass that is a transparent window, which allows a view into the accumulator **22**. An operator (e.g., a user, etc.) can view into the site glass to see a level of liquid within the vessel (e.g., accumulator **22**). In some examples, the indicator **26** can be an optical sensor that may include an infrared LED and a light transistor. The LED can project light through the liquid (e.g., working fluid **38**), which bounces back to the transistor. The amount of light returned to the transistor affects the output level. That is, the optical sensor can indicate the working fluid level **44** (e.g., amount of working fluid **38**) in the accumulator **22**.

The evaporator **18** can have a plurality of operating conditions **46**, each of which may indicate an overall functioning of the fluid compression system **10**. The plurality of operating conditions **46** relevant to an evaporator **18** can include: a full load operating condition **46-1** (shown in FIG. **3**A); a partial load operating condition **46-2** (shown in FIG. **3**B); a shut-down operating condition **46-3** (shown in FIG. **5**); and a start-up operating condition (not shown). The plurality of operating conditions **46** (e.g., **46-1**, **46-2**, **46-3**) are generally referred to herein as operating condition(s) **46**. In some embodiments, additional operating conditions **46** may be relevant to the evaporator **18**.

Each of the plurality of operating conditions **46** relative to the evaporator **18** may correspond to a particular working fluid level among a plurality of working fluid levels **44** in the accumulator **22**. The plurality of working fluid levels **44** can include a full load working fluid level **44-1** (shown in FIG. **3**A); a partial working fluid level **44-2** (shown in FIG. **3**B); a working fluid loss level **44-3** (shown in FIG. **4**); and a start-up operating working fluid level (not shown). The plurality of working fluid levels **44** (e.g., **44-1**, **44-2**, **44-3**) are generally referred to herein as working fluid level(s) **44**.

The plurality of operating conditions **46** relative to the evaporator **18** and the plurality of working fluid levels **44** in the accumulator **22** will be discussed further herein with respect to FIGS. **3**A-**5**.

FIG. **3**A illustrates the accumulator in a fluid compression system **10** according to a first embodiment. FIG. **3**A illustrates a full load operating condition **46-1** associated with the evaporator **18**.

A full load operating condition **46-1** is a fully charged evaporator **18**. The tube bundle **40** in the evaporator **18** can be covered (e.g., submerged) in working fluid **38**. The evaporator **18** can heat the charge to vapor **42**. The vapor **42** (e.g., working fluid **38** in gas state) can travel through a third conduit **60** to the compressor **12**. The full load operating condition **46-1** can have an increased void fraction of the working fluid **38** in evaporator **18** compared to a partial load operating condition **46-2**, as described further herein with respect to FIG. **3**B. The increased void fraction can reduce the mass of working fluid **38** in the evaporator **18**. The reduction of charge level in the evaporator **18** is transferred into the accumulator **22**, increasing the charge spill-over rate. That is, a fully charged evaporator **18** can increase the charge spill-over rate of working fluid **38** as the void fraction of the working fluid **38** increases.

As the charge spill-over rate increases, a working fluid level **44** in the accumulator **22** can increase. A full load working fluid level **44-1** in the accumulator **22** can correlate to the full load operating condition **46-1** relative to the evaporator **18**. That is, an increased (e.g., high) amount of charge spill-over from the evaporator **18** into the accumulator **22** can increase the working fluid level **44** (e.g., amount) stored in the accumulator **22**. When the rate of charge density in the evaporator **18** is at or about 0, the charge spill-over rate may decrease to a rate equal to the rate of the fluid leaving the accumulator **22** (e.g., via conduit **28**).

The working fluid level **44** in the accumulator **22** can indicate the operating condition **46** relative to the evaporator **18**. For example, a high level of working fluid **38** (e.g., full load charge level **44-1**) in the accumulator **22** can indicate the full load operating condition **46-1** relative to the evaporator **18**. In an embodiment, the increased amount of charge from the evaporator **18** can be stored in the accumulator **22** until the evaporator **18** requires the working fluid **38**, such as when operating in a different operating condition **46**, as discussed further herein.

For example, working fluid **38** (e.g., refrigerant and lubricant mixture) can be provided from the evaporator **18** to the accumulator **22** via the spill over port **24** when in a full load operating condition **46-1**. The working fluid **38** can drain from the accumulator **22** into the first conduit **28** for circulation in the fluid compression system **10**. The working fluid **38** drained to the first conduit **28** can be provided to the compressor **12** via compressor suction. From the compressor **12**, the working fluid **38** can flow to the condenser **14**, through the second conduit **30**, and to the expansion device **16**. The expansion device **16** includes an expansion valve **58** that can be opened (e.g., unsealed) to allow flow to the evaporator **18** or closed (e.g., sealed) to prevent flow to the evaporator **18**. The expansion valve **58** can be opened or closed in response to the operating condition **46** relative to the evaporator **18**. When the evaporator **18** is functioning in a full load operating condition **46-1**, the expansion valve **58** is open to allow working fluid **38** to flow through the fluid compression system **10**.

In some instances, lubricant (e.g., oil) can collect in the evaporator **18** when there is a lack of working fluid **38** (e.g., working fluid loss, loss of refrigerant, etc.) in the evaporator **18**, which can cause a problem in the functioning of the fluid compression system **10**. When there is working fluid loss, the accumulator **22** may provide working fluid **38** to the system **10** via the first conduit **28** until charge spills over via the spill over port **24** and balance is reestablished in the fluid compression system **10**, as discussed further herein.

FIG. **3**B illustrates the accumulator in the fluid compression system according to a second embodiment. FIG. **3**B illustrates a partial load operating **46-2** condition associated with the evaporator **18**.

A partial load operating condition **46-2** is an adequately charged evaporator **18**. The partial load operating condition **46-2** is the amount of working fluid **38** that can enable the system **10** to properly function under operating conditions that are less than full load.

The partial load operating condition **46-2** can have a decreased void fraction in evaporator **18** compared to full load operating condition **46-1**. A reduction in void fraction increases a charge density in the evaporator **18**. The mass of working fluid may then be obtained from the accumulator **22**. A change in the operating condition from the full load **46-1** to a partial load **46-2** decreases the void fraction (e.g. volume) of charge **38** in the evaporator **18**. The decreased volume may decrease the charge level within the evaporator **18**, which can cause a reduction in the charge spill-over rate. The decreased charge spill-over rate is a decrease of working fluid **38** spilling over into the accumulator **22**, which can decrease a working fluid level **44** in the accumulator **22**. The working fluid level **44** stored in the accumulator **22** decreases because the charge flow rate decreases from the evaporator **18** while working fluid **38** drains from the accumulator **22** into the first conduit **28**. That is, the charge spill over rate is less than an amount of working fluid **38** flowing to the conduit **28**. An increased charge level in the evaporator **18** can increase the charge spill-over rate until the charge spill-over rate matches the flow rate leaving the accumulator **22**. The working fluid **38** stored in the accumulator **22** can aid in maintaining operation of the system **10**.

A partial working fluid level **44-2** in the accumulator **22** can correlate to the partial load operating condition **46-2** associated with the evaporator **18**. A decreased (e.g., low) amount of charge (e.g., working fluid **38**) spill-over from the evaporator **18** into the accumulator **22** can decrease the working fluid level **44** (e.g., amount) stored in the accumulator **22**. That is, the charge spill-over may not replace the amount of working fluid **38** flowing to the first conduit **28**. The indicator **26** can detect (e.g., measure) the working fluid level **44**. As such, a partial working fluid level **44-2** sensed by the indicator **26** in the accumulator **22** can indicate the partial load operating condition **46-2** of the evaporator **18**.

The working fluid **38** from the accumulator **22** can supplement the vapor **42** from the evaporator **18** for proper functioning of the system **10**. The working fluid **38** can travel to the compressor **12**, condenser **14**, through the second conduit **30**, and to the expansion device **16**. The expansion valve **58** can be opened to allow the working fluid **38** to return to the evaporator **18**. Depending on the amount of working fluid **38** returned, the operating condition **46** may or may not change in response.

In an embodiment, at certain partial working fluid levels (e.g., **44-2**), the level at partial load can indicate the lowest level at which the system **10** may function. The tube bundle **40** can be covered by working fluid **38**, the compressor **12** can have adequate lubrication, the condenser **14** can hold sufficient working fluid, etc. In other words, the partial working fluid level **44-2** can indicate the minimum amount of charge required by the system **10** to properly function. In an embodiment, the partial working fluid level **44-2** can be a threshold level. When the working fluid level **44** in the accumulator **22** is at or below a threshold level (e.g., the minimum amount of working fluid **38** in the system **10** for proper operation), the evaporator **18** can initiate a shut-down operating condition to prevent damage to the system **10**, as discussed further with respect to FIGS. **4** and **5**.

It may be noted that in some examples, the variation in charge between a full load operating condition **46-1** and a partial load operating condition **46-2** associated with an evaporator **18** can be approximately less than ten pounds.

FIG. **4** illustrates the accumulator in the fluid compression system according to a third embodiment. FIG. **4** illustrates a working fluid loss level **44-3** that indicates working fluid loss (e.g., a charge loss operating condition) associated with the evaporator.

When the working fluid level **44** in the accumulator **22** is below the partial working fluid level **44-2** (e.g., the threshold level), a working fluid loss level **44-3** can be detected by the indicator **26**. A working fluid loss level **44-3** in an accumulator **22** can indicate an inadequately charged evaporator (e.g., **18** in FIGS. **3**A and **3**B). That is, an evaporator may have experienced loss of working fluid (e.g., **38** in FIGS. **3**A and **3**B) and/or may have a working fluid **38** imbalance in the evaporator, leading to a working fluid loss level **44-3** in the accumulator **22**.

The working fluid/charge loss may be an indication of a leak in the system (e.g., fluid compression system **10** in FIGS. **3**A and **3**B).

The loss of working fluid in the evaporator may substantially decrease the working fluid level **44** in the accumulator **22**. As working fluid **38** drains from the accumulator **22** to the first conduit **28**, the amount of charge is not replaced via spill-over, which creates a deficit. That is, the loss of charge can decrease an amount of working fluid spilling over into the accumulator **22**, thereby decreasing the amount of working fluid **38** stored in the accumulator **22**.

In some embodiments, the charge spill-over rate may cease completely. The evaporator **18** may be unable to supply working fluid (e.g., **38** in FIGS. **3**A and **3**B) to the accumulator **22** due to increased vaporization of working fluid in the evaporator and/or not enough working fluid. That is, if the charge loss in the system is severe, the evaporator may not have charge (e.g., working fluid **38**) reaching the spill over port **24**, and thus charge spill-over may not be possible until working fluid **38** returns to the evaporator **18**. If the charge loss is such that there is a lack of charge spill-over from the evaporator to the accumulator **22**, lubricant may accumulate in the evaporator, which can cause foaming and high energy consumption until an adequate charge spill-over rate is reestablished.

A substantially decreased (e.g., low, completely cease flow, etc.) amount of charge spill-over from the evaporator into the accumulator **22** can substantially decrease the working fluid level **44** (e.g., amount) stored in the accumulator **22**. The indicator **26** may detect the decreasing amount, which can indicate charge loss in the evaporator **18**. As such, a working fluid loss level **44-3** relative to the accumulator **22** can indicate lack of working fluid associated with the evaporator, which may lead to a shut-down operating condition (e.g., **46-3**), discussed further with respect to FIG. **5**.

In some embodiments, the indicator **26** can detect the working fluid loss level **44-3**. The working fluid loss level **44-3** can be an amount of working fluid **38** that is below a partial working fluid level **44-2** (e.g., threshold level), while the charge loss in the evaporator may indicate increased lubricant (e.g., in FIGS. **3**A and **3**B) accumulation in the evaporator (e.g., **18** in FIGS. **3**A and **3**B). The working fluid loss level **44-3** in the accumulator **22** can indicate a charge loss in the evaporator. Charge loss in an evaporator **18** is when inadequate levels of charge (e.g., working fluid **38**) and/or an accumulation of lubricant is present within the evaporator **18**, which prevents proper functioning (e.g., lubrication, cooling, etc.) of the fluid compression system **10**.

The loss of working fluid/charge can pose danger to the system **10** if operation continues. In an embodiment, the working fluid loss level **44-3** in the evaporator **18** is detected by the indicator **26**, which can trigger an alarm and/or initiate a shut-down operating condition **46-3**. For instance, as illustrated in FIG. **4**, a working fluid level **44** at or below the working fluid loss level **44-3** may initiate a shut-down operating condition to prevent damage to the system, as discussed further herein with respect to FIG. **5**.

FIG. **5** illustrates an embodiment of the accumulator **22** in the fluid compression system **10**, according to a fourth embodiment. FIG. **5** illustrates a shut-down operating condition **46-3** associated with the evaporator **18**.

As illustrated in FIG. **5**, the accumulator **22** is disposed on the outside of the evaporator **18**. Although illustrated external to the evaporator **18**, it will be appreciated that the accumulator **22** may be located in various locations of the evaporator **18**. For example, the accumulator **22** can be disposed on any of the sides of the evaporator **18**, and internal or external to the evaporator **18** in the fluid compression system **10**.

In the fluid compression system **10**, such as a chiller unit as part of an HVACR system, it may be desired to initiate a shut-down operating condition **46-3** to remove the charge (e.g., working fluid **38**) from the evaporator **18**. A shut-down operating condition **46-3** can be used to remove all of, or a significant portion of the charge **38** from the evaporator **18** to permit re-charging of the evaporator **18**, prevent possible freezing or damage to the tube bundle **40**, and/or maintenance purposes. In other words, the shut-down operating condition **46-3** can cause the charge to move from the evaporator **18** to the accumulator **22**. The charge is diverted from the evaporator **18** by closing the expansion valve **58** of the expansion device **16** and opening the fill and drain valve **50**, which allows high pressure refrigerant to flow from the condenser **14** into the accumulator **22**. The working fluid **38** is primarily stored as a liquid. A portion of the diverted refrigerant can flash to vapor **42**. The vapor **42** can flow through line **24** to the evaporator **18** to be removed by the compressor **12**. The working fluid **38** can be stored for a period of time in the accumulator **22**. Since the expansion valve **58** is closed (e.g., sealed) and the fill and drain valve **50** is open (e.g., unsealed), the working fluid **38** is stored as liquid in the accumulator **22**.

In an embodiment, when the indicator **26** detects a working fluid **38** below a partial working fluid level **44-2** or at a working fluid loss level **44-3** in the accumulator **22**, the indicator **26** can send a signal to a controller **56** associated with the system **10**. The indicator **26** can send a working fluid level measurement (e.g., detection) to the controller **56**. As illustrated in FIG. **5**, the controller **56** is connected to the expansion device **16**, the indicator **26**, and the fill and drain valve **50** of accumulator **22** via dashed lines to indicate an electrical connection. The controller **56** is configured to receive the working fluid level **44** measured by the indicator **26**. The controller **56** is further configured to control the fill and drain valve **50** and the expansion device **16** according to signals (e.g., inputs) from the indicator **26**.

The controller **56** can initiate a shut-down operating condition **46-3** in response to the detected working fluid loss level **44-3** to permit maintenance and/or prevent damage to the system **10**. The working fluid loss level **44-3** can correspond to the shut-down operating condition **46-3** of the evaporator **18**. By initiating a shut-down operating condition **46-3** upon the detection of a working fluid loss level **44-3** (e.g., threshold level), the system **10** can avoid damage. That is, a shut-down operating condition **46-3** may be used for maintenance purposes and/or prevention of freezing, tube bundle **40** damage, and/or damage to the system **10**.

The shut-down operating condition **46-3** can initiate the fluid compression system **10** to remove all of, or a significant portion of the charge from the evaporator **18**. The working fluid **38** can be stored in the accumulator **22**. For example, the portion of charge (e.g., working fluid **38**) that had been in the evaporator **18** can be moved, via boiling, to the accumulator **22** for storage for a period of time.

To restart the fluid compression system, as illustrated in FIG. **5**, a fill and drain valve **50** can be connected to the accumulator **22** in an embodiment. The fill and drain valve **50** can be used to drain the stored working fluid **38** (e.g., working fluid level **44**) into the evaporator **18** until the charge in the evaporator **18** meets the spillover port **24** and establishes charge balance in the fluid compression system **10**. Balance is restored when a charge (e.g., working fluid **38**) spill-over rate is reestablished in the fluid compression system **10**, such that the evaporator **18** is operating at or above a partial load operating condition **46-2**. That is, the accumulator **22** at least has a partial working fluid level **44-2** and the evaporator **18** is operating at a partial load operating condition **46-2** or at a full load operating condition **46-1**.

The controller **56** can be configured to open or close the fill and drain valve **50** and/or the expansion device **16** so as to regulate the working fluid **38** flowing to the evaporator **18**. Regulating the working fluid flow to the evaporator **18** can result in changes to the amount of working fluid **38** in the evaporator **18**, condenser **14**, as well as the amount of working fluid **38** in the accumulator **22**. As such, the controller **56** can regulate a distribution of working fluid **38** through the fluid compression system **10**.

In an embodiment, a start-up operating condition can be associated with the evaporator **18**. The start-up operating condition can correspond to a start-up working fluid level in the accumulator **22**. That is, the start-up operating condition relevant to the evaporator **18** can drain the stored working fluid **38** from the accumulator **22** to the evaporator **18** to establish balance in the system **10**. For example, the working fluid level **44** in the accumulator **22** may be fluctuating between a high working fluid level (e.g., **44-1**) and a partial working fluid level (e.g., **44-2**) depending upon the amount of working fluid **38** drained from the accumulator **22** via the fill and drain valve **50** to the evaporator **18**.

In an embodiment, the evaporator **18** can include one or more flow control devices **52** located for example between the evaporator **18** and the spill over port **24**. In an embodiment, the flow control device **52** is a valve which can be automatically and/or actively controlled by the controller **56** of a unit (e.g., fluid compression system **10**) or a system controller, which controls multiple units and/or devices (e.g. in a building). The flow control device **52** can control working fluid **38** flow from the evaporator **18** into the accumulator **22**. It will be appreciated that the flow control device **52** can be any suitable valve whether controlled or manually operated. For example, the flow control device **52** can be opened or closed to control the flow of working fluid **38** from the evaporator **18** to the accumulator **22**. In some circumstances, the flow control device **52** is a manually operated valve, for example in a system which uses maintenance pump down and not operational pump down.

A goal of the shut-down operating condition **46-3** is to empty an amount of charge **38** from the evaporator **18**. For example, the evaporator **18** may be emptied in preparation for a re-charging of the system **10**. It will be appreciated that shut-down operating condition **46-3** can also be done for maintenance or service, such as when the indicator **26** detects a working fluid loss level **44-3** and/or to properly charge the fluid compression system **10**.

Generally, the amount of charge to be removed from the evaporator **18** can vary depending on the fluid compression system **10** design. Generally, at least a sufficient amount of charge (e.g., working fluid **38**) is removed so as not to be susceptible to freezing or to a level of freezing which may be harmful and/or undesired. The accumulator **22** can be sized and located appropriately to meet the system design, and may include more than one accumulator **22**. For example, in some embodiments, a plurality of accumulators (e.g. multiple **22***s*) may be fluidly connected to the evaporator **18** via a plurality of charge spill-over ports (e.g., multiple **24***s*). The evaporator **18** can provide charge to the plurality of accumulators to store additional working fluid. In some instances, the plurality of accumulators may store different volumes of working fluid depending on the location of the respective charge spill-over port connected to the evaporator **18**.

In some embodiments, the accumulator **22** can effectively increase the volume of the condenser **14**, and as such, the accumulator **22** may remove the need for storage of working fluid **38** in the condenser **14** (e.g. when using a microchannel heat exchanger for the condenser **14**). Additionally, and/or alternatively, because the working fluid does not contact evaporator **18** tubes, an isolation valve may not be required.

By adding the fill and drain valve **50** to the accumulator **22**, the accumulator **22** can be used to store (e.g., fill) the working fluid **38** upon a shut-down operating condition **46-3** of the evaporator **18** and restore (e.g., drain) working fluid **38** from the accumulator **22** to restore charge to the evaporator **18** after the shut-down operating condition **46-3** (e.g., for startup). For example, the evaporator **18** can boil/vaporize **42** the working fluid **38**, which can flow through a third conduit **60**, to the compressor **12**, and through the condenser **14**. The fill and drain valve **50** can be opened so that the accumulator **22** can store the working fluid **38** flowing through the condenser **14**, while the expansion device **16** can be closed to isolate the vaporization **42** of the remaining working fluid **38** in the evaporator **18**. In an embodiment, the remaining working fluid **38** in the evaporator **18** is collected in the accumulator **22** during a shut-down operating condition **46-3**.

By closing the expansion valve **58** and opening the fill and drain valve **50**, the accumulator **22** becomes part of the condenser **14** circuit. The compressor **12** can be used to boil the charge (e.g., working fluid **38**, refrigerant, mixture, etc.) out of the evaporator **18**. In some embodiments, a check valve **54** can be located for example between the condenser and the compressor **12** to prevent backwards flow from the condenser **14**. The check valve **54** prevents working fluid from flowing back into the compressor **12**, thereby preventing damage to the compressor **12**. The expansion device **16** may shut off (e.g., close) with a leak tight seal. Closing the fill and drain valve **50** can complete isolation of the circuit.

Upon a restart operating condition, the expansion valve **58** can be opened while the fill and drain valve **50** remains open to refill the evaporator **18** and enable the system **10** to operate at a full-load operating condition (e.g., **46-1**) or a partial load operating condition (e.g., **46-2**). The working fluid **38** stored in the accumulator **22** can be drained to the second conduit **30** and through the expansion device **16** to be provided to the evaporator **18**. The working fluid **38** can travel through the expansion device **16** and to the evaporator **18** where the working fluid **38** can be provided to the accumulator **22** via the spill-over port **24**.

Additionally, or alternatively, in some embodiments, sub-cooling control can keep a mass of charge **38** in the condenser **14** fixed. The sub-cooling can help to maintain a mass flow balance between the compressor **12** and the expansion device **16**. The sub-cooling can minimize charge variation in the condenser **14** so it may operate at peak efficiency. The working fluid **38** (e.g., refrigerant) draining from the accumulator **22** into the first conduit **28** can eventually collect in the evaporator **18** until charge spills over via the spill over port **24** and balance is reestablished in the fluid compression system **10**.

Additionally, or alternatively, in some embodiments, the indicator **26** can detect a transition operating condition associated with the evaporator **18**. For example, the indicator **26** may detect a working fluid level **44** in the accumulator **22** that fluctuates between a working fluid loss level **44-3** and a partial working fluid level **44-2**. When the fill and drain valve **50** is closed, the accumulator **22** can store the working fluid **38** that spills over from the evaporator **18**. In response to the operating condition **46** relative to the evaporator **18**, the working fluid level **44** can fluctuate. The fluctuation between the two different working fluid levels **44** can indicate a transition operating condition associated with the evaporator **18**. The working fluid level **44** in the accumulator **22** indicates the evaporator **18** is operating a partial load operating condition **46-2** for a period of time, and operating with working fluid loss for a different period of time. The working fluid level **44** in the accumulator can fluctuate without triggering a shut-down operating condition **46-3** in the evaporator **18** for a predetermined period of time.

The indicator **26** can send a signal indicating the working fluid loss level **44-3** to the controller **56**. The controller **56** may not initiate a shut-down operating condition **46-3** until the working fluid loss level **44-3** has been indicated by the indicator **26** for a predetermined period of time to account for the transition operating condition. That is, there may be a period of time at which the indicator **26** measures a working fluid loss level **44-3** in the accumulator **22** before achieving a partial working fluid level **44-2**. Provided the working fluid loss level **44-3** does not exceed the predetermined period of time, the system **10** may not enter a shut-down sequence via the controller **56** since the predetermined time period can be construed as a transient or a false positive condition. In other words, the controller **56** of the fluid compression system **10** may not initiate a shut-down operating condition **46-3** upon detection of a working fluid loss level **44-3** unless the working fluid loss level **44-3** is detected for a predetermined period of time to account for transition operating conditions. Accounting for the transition operating conditions can prevent an unnecessary shut-down operating condition **46-3**.

It will be appreciated that as long as there is working fluid **38** in the accumulator **22**, there will be lubricant return to the evaporator **18** within the heating exchanger system **10**, such that the system **10** can continue to properly function via the various operating conditions **46**.

It is to be appreciated that the embodiments and principles described herein may be adapted to use with any other fluid containing apparatus.

With regard to the foregoing description, it is to be understood that changes may be made in detail, without departing from the scope of the present invention. It is intended that the specification and depicted embodiments are to be considered exemplary only, with a true scope and spirit of the invention being indicated by the broad meaning of the claims.

The invention claimed is:

1. A fluid compression system, comprising:

a compressor;

a condenser, an expansion device, and an evaporator fluidly connected to the compressor;

an accumulator fluidly connected to the evaporator via a spillover port, the spillover port directs working fluid received from the evaporator to be collected and stored in the accumulator;

a first conduit fluidly connected to the accumulator and the compressor, the first conduit configured to direct lubricant from the accumulator to the compressor;

a fill and drain valve fluidly connected to the accumulator; and

a second conduit fluidly connected to the accumulator and at a location disposed fluidly between an outlet of the condenser and an inlet of the expansion device, the fill and drain valve disposed in the second conduit, the fill and drain valve configured to release working fluid stored in the accumulator to the second conduit, wherein actuation of the fill and drain valve is in response to a start-up operating condition relative to the evaporator,

wherein the working fluid is stored and released from the accumulator in response to an operating condition of the evaporator.

2. The system of claim **1**, wherein the operating condition is among a plurality of operating conditions, and each operating condition among the plurality of operating conditions is relative to the evaporator and corresponds to a working fluid level in the accumulator.

3. The system of claim **2**, wherein the plurality of operating conditions include:

a full load operating condition that corresponds to a full load working fluid level in the accumulator;

a partial load operating condition that corresponds to a partial working fluid level in the accumulator;

a shut-down operating condition that corresponds to a working fluid loss level in the accumulator; and

a start-up operating condition that corresponds to a start-up working fluid level in the accumulator.

4. The system of claim **1**, further comprising an indicator, the indicator configured to:

detect a working fluid level in the accumulator, wherein the detected working fluid level in the accumulator corresponds to an amount of charge and particular operating condition associated with the evaporator; and

identify, via the detected level of working fluid the accumulator, a partial load operating condition at which the fluid compression system operates.

5. The system of claim **1**, further comprising a controller to initiate a shut-down operating condition when an indicator detects a working fluid loss level stored in the accumulator for a predetermined period of time.

6. The system of claim **1**, further comprising an indicator located at least partially within the accumulator, wherein the indicator is configured to:

detect a working fluid level in the accumulator, the working fluid level corresponds to a stored charge amount and the operating condition relevant to the evaporator; and

provide an indication to a controller of the fluid compression system of a detected working fluid loss level that corresponds to a charge loss operating condition relative to the evaporator.

7. The system of claim **1**, wherein the operating condition of the evaporator is a transition operating condition, and

the transition operating condition corresponds to a transition working fluid level of the accumulator, and wherein the transition operating condition does not initiate a shut-down operating condition.

8. The system of claim **7**, wherein the transition operating condition indicates a partial working fluid level in the evaporator for a predetermined time to prevent a false charge loss indication.

9. The system of claim **1**, wherein the accumulator is external to the evaporator, and a working fluid spill-over rate from the evaporator to the accumulator is directly correlated.

10. A cooling system, comprising:

a compressor;

a condenser fluidly connected to the compressor;

an evaporator fluidly connected to the compressor;

an expansion device fluidly connected to the evaporator and the condenser;

an accumulator fluidly connected to the evaporator;

a fill and drain valve fluidly connected to the accumulator, the fill and drain valve arranged to release working fluid stored in the accumulator to pass from the accumulator to the expansion device and evaporator based on an operating condition of the evaporator;

a first conduit fluidly connected to the accumulator and the compressor, the first conduit configured to direct lubricant from the accumulator to the compressor;

a second conduit fluidly connected to the accumulator and at a location between an outlet of the condenser and an inlet of the expansion device, the fill and drain valve disposed in the second conduit.

11. The cooling system of claim **10**, wherein working fluid is released from the accumulator via the fill and drain valve in response to a start-up operating condition relative to the evaporator.

12. The cooling system of claim **10**, wherein the fill and drain valve is opened and an expansion valve of the expansion device is closed in response to a shut-down operating condition to isolate a vaporization of the working fluid in the evaporator.

13. The cooling system of claim **12**, wherein the fill and drain valve is opened and the expansion valve is opened in response to a start-up operating condition relative to the evaporator, wherein the accumulator provides stored working fluid to the evaporator.

14. The cooling system of claim **10**, further comprising an indicator located at least partially within the accumulator, wherein the indicator is a level sensor.

15. The cooling system of claim **14**, wherein the indicator detects a working fluid level within the accumulator, the working fluid level correlates to the operating condition of the evaporator.

16. The cooling system of claim **14**, wherein the indicator is configured to provide an indication of a working fluid loss charge level to a controller that correlates to a shut-down operating condition in the evaporator.

17. A method of controlling a fluid compression system, comprising:

detecting, via an indicator, a working fluid level stored in an accumulator;

correlating the working fluid level to an operating condition among a plurality of operating conditions relative to an evaporator;

storing, in the accumulator, an amount of charge provided from the evaporator in response to the operating condition, wherein the working fluid level increases or decreases depending upon the operating condition; and

actuating a fill and drain valve fluidly connected to the accumulator, the fill and drain valve fluidly disposed at a location between an outlet of a condenser and an inlet of an expansion device based on the operating condition of the evaporator.

18. The method of claim **17**, further comprising initiating, via a controller, a shut-down operating condition relative to the evaporator in response to the working fluid level being less than a working fluid threshold level, wherein charge from the evaporator at least substantially fills the accumulator.

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